10/24/07

Perspectives in dA at RHIC

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The main question: Have we indeed discovered a new physics at low x?

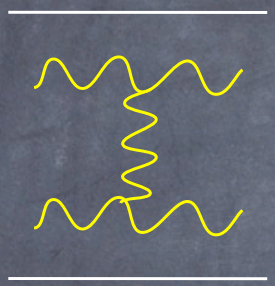
If yes:
- what are its unique features?
- in what kinematic region does it hold?

Key measurements

- Hadron spectra and multiplicities
- Heavy quark spectra and multiplicities
- J/ψ
- Correlations
- Prompt photons and di-leptons
- Energy dependence - LHC
- Identified hadrons
- Diffraction

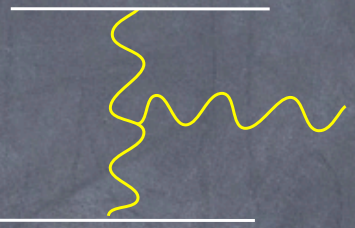
Inclusive hadrons

- What is the hadron production mechanism?



factorized pQCD

vs

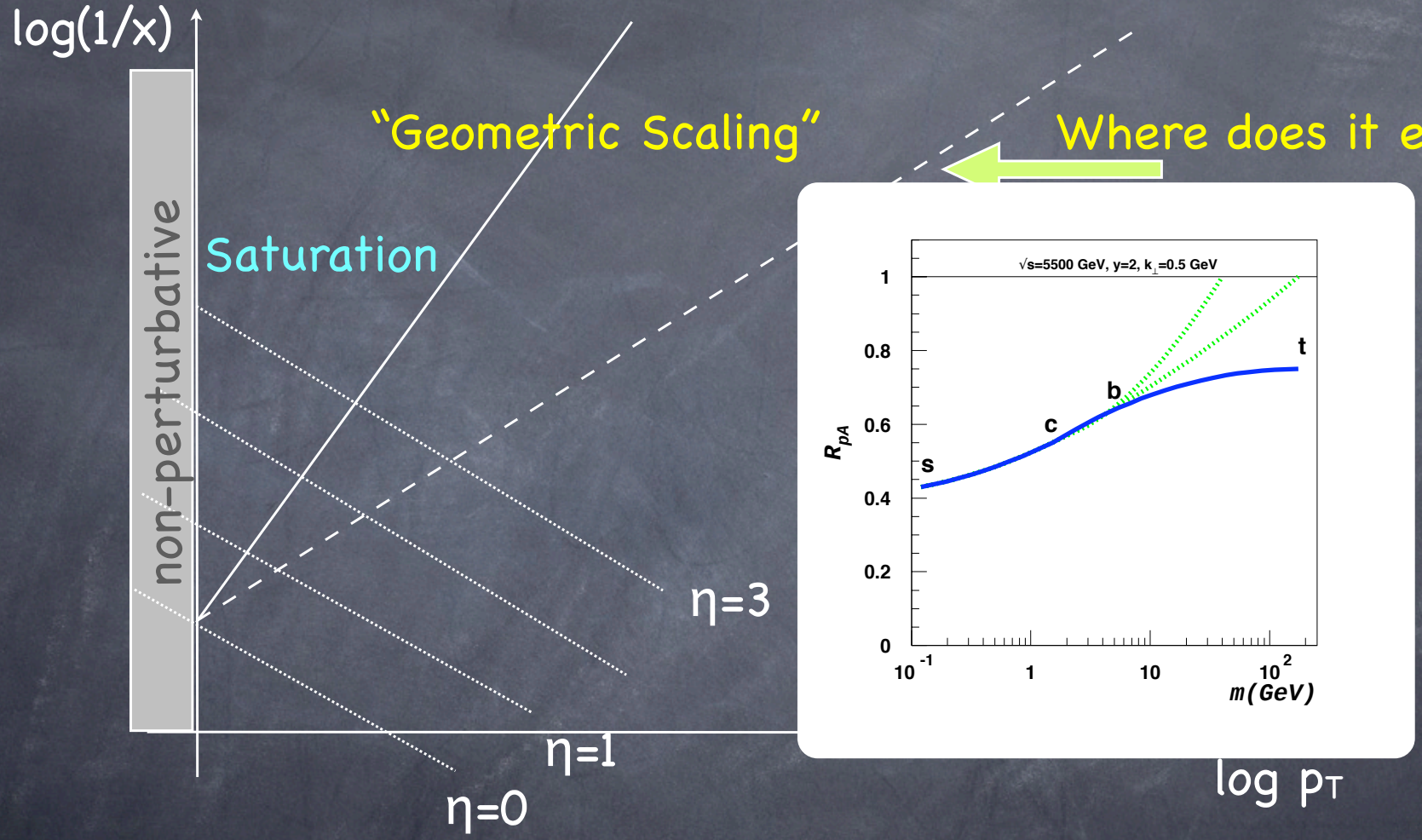


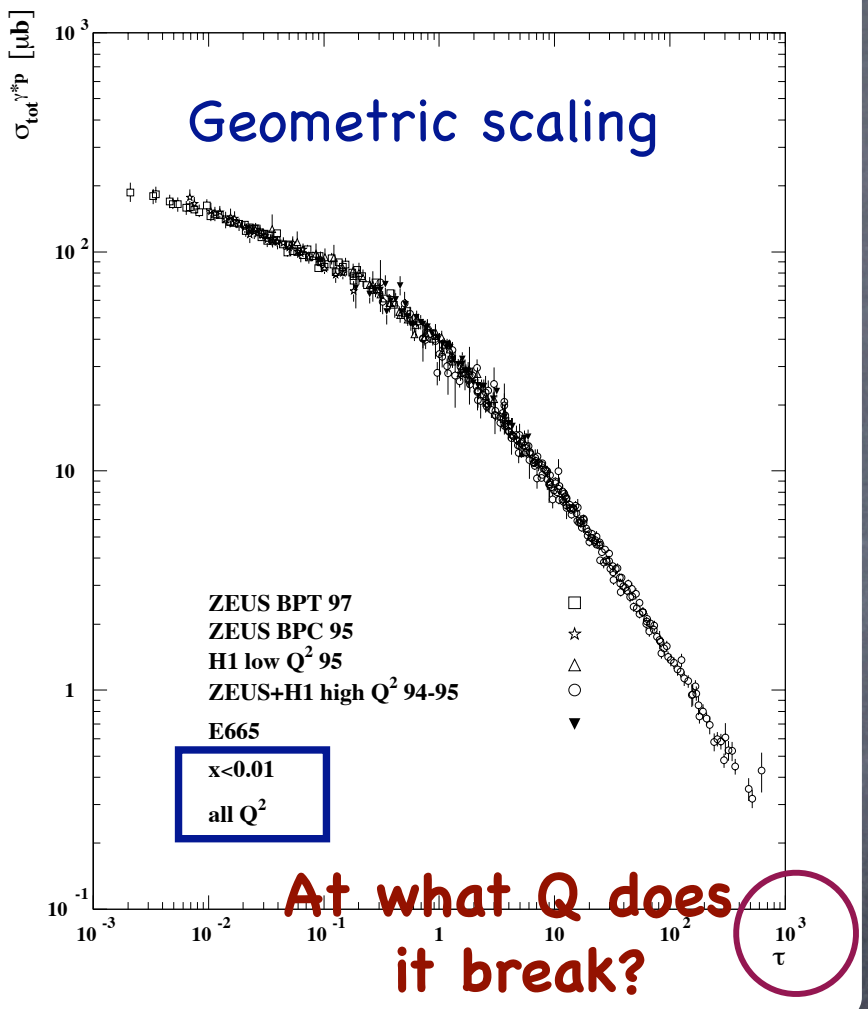
gluon saturation

Shadowing and evolution are separated

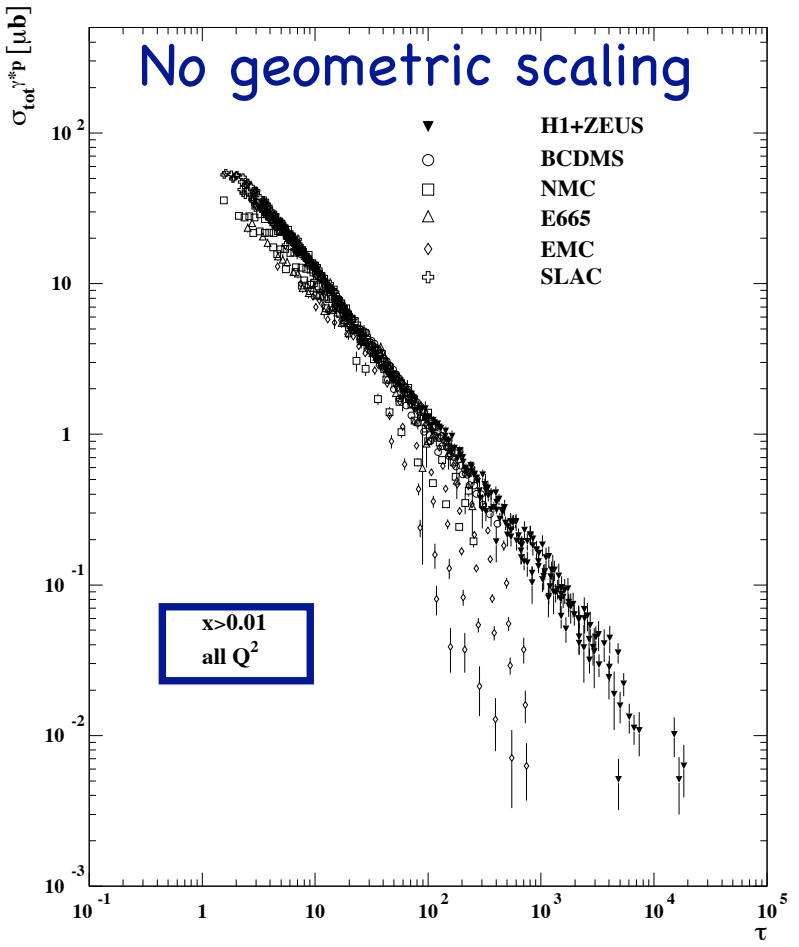
Interplay of nuclear shadowing and QCD evolution

Gluon Saturation = CGC = $Q_s(x,A)$


log(1/x)
non-perturbative
Saturation
"Geometric Scaling"
Where does it end?
η=3
η=1
η=0
log pT
√s=5500 GeV, y=2, k⊥=0.5 GeV
R_pA
s
c
b
t
m(GeV)



At what Q does it break?



CGC vs pQCD: important parameters

1. How small is x? x determines "the coherence length" $l_c=1/xM_N$ If $l_c>>R_A$, color fields of nucleons add up to create a strong nuclear field. Otherwise - only fields of an individual nucleons matter.

✳ If x is even smaller $x\sim e^{-1/\alpha}$ gluons start to saturate the high p_T modes

2. How big is A? $\alpha^2 A^{1/3} \sim 1$ is a condition for a strong field.

3. How big is p_T? pQCD works if $p_T >> 1GeV$

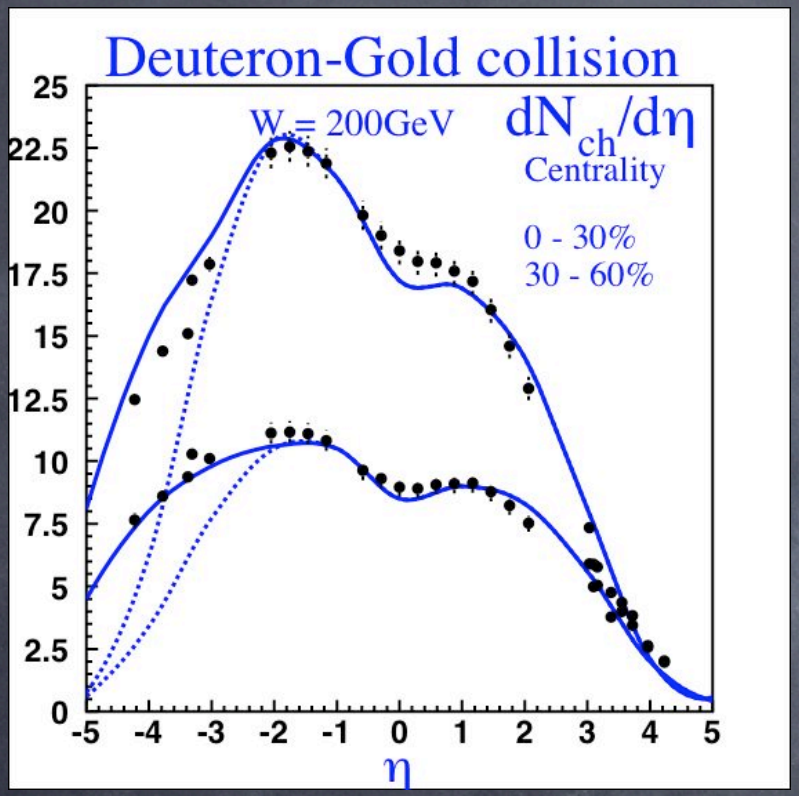
✳ If p_T is even larger $p_T \sim \Lambda e^{1/\alpha}$ hard pQCD is at work (DGLAP)

CGC vs Shadowing models

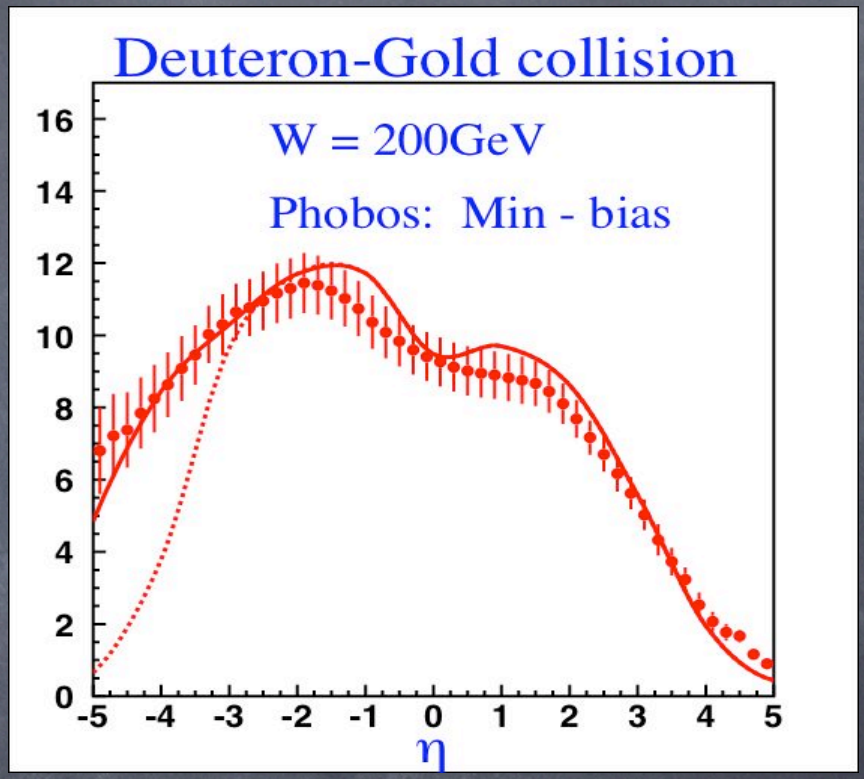
- CGC approach: provides a theory of a new physics at x<<1. Not absolutely clear how to match onto pQCD at high p_T and/or x~1

- Shadowing models: there is no new physics at x<<1, but only a few disconnected effects in conventional pQCD. Has trouble when confronted with the data.

Hadron multiplicities in dAu at RHIC



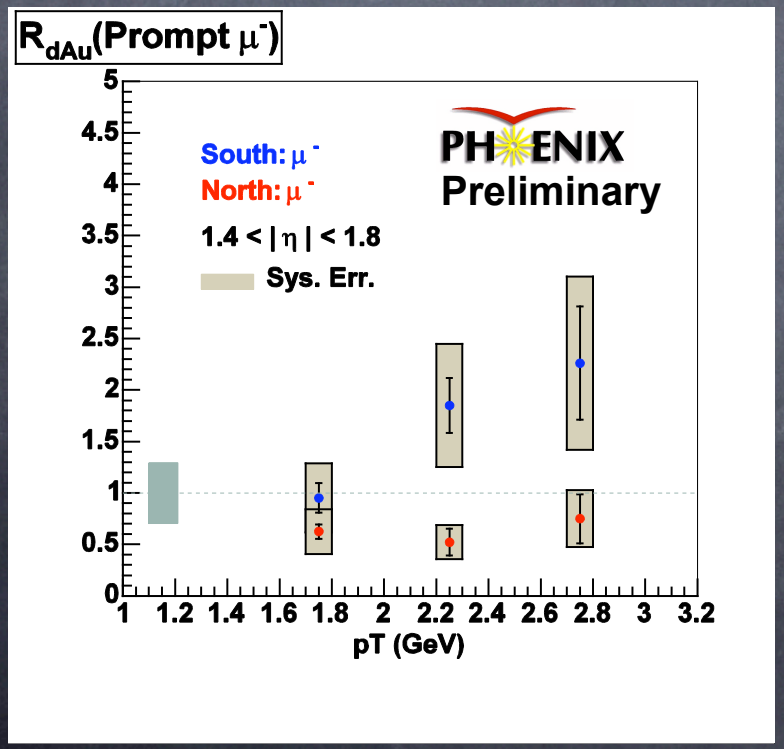
BRAHMS



PHOBOS

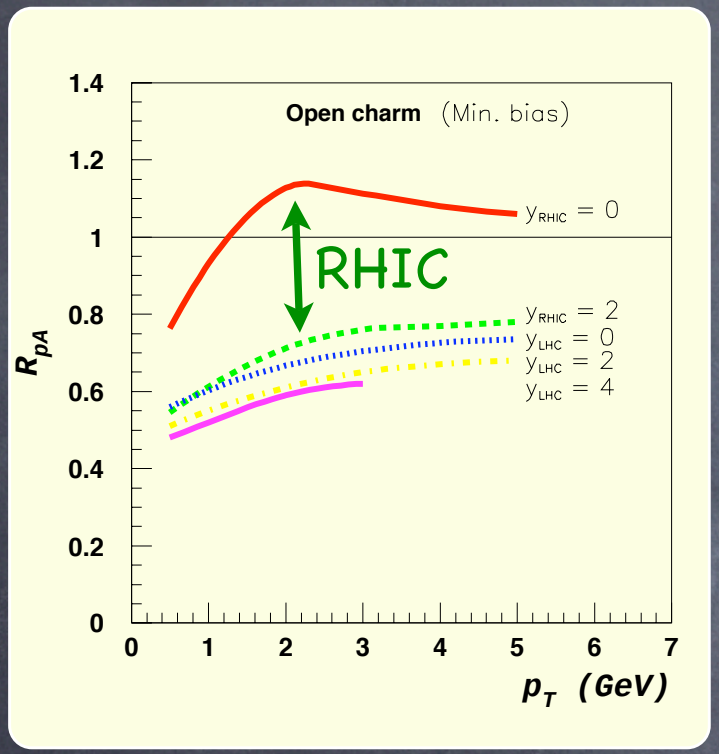
Hadron production

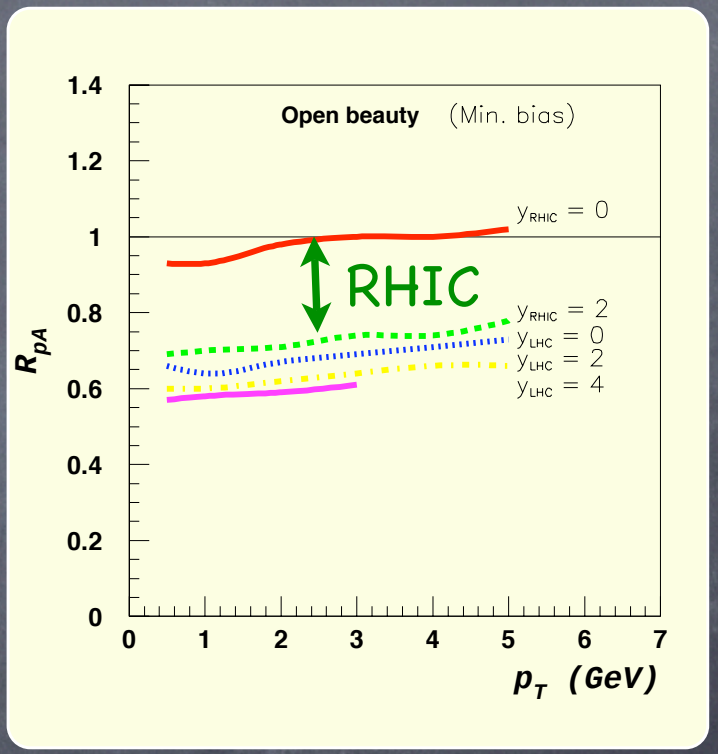
- We need high p_T measurements to see the transition to pQCD.
- Open charm at forward rapidities - ???



Presented by R. Averbeck at 2006 RHIC & AGC Users' Meeting

Expectations at LHC

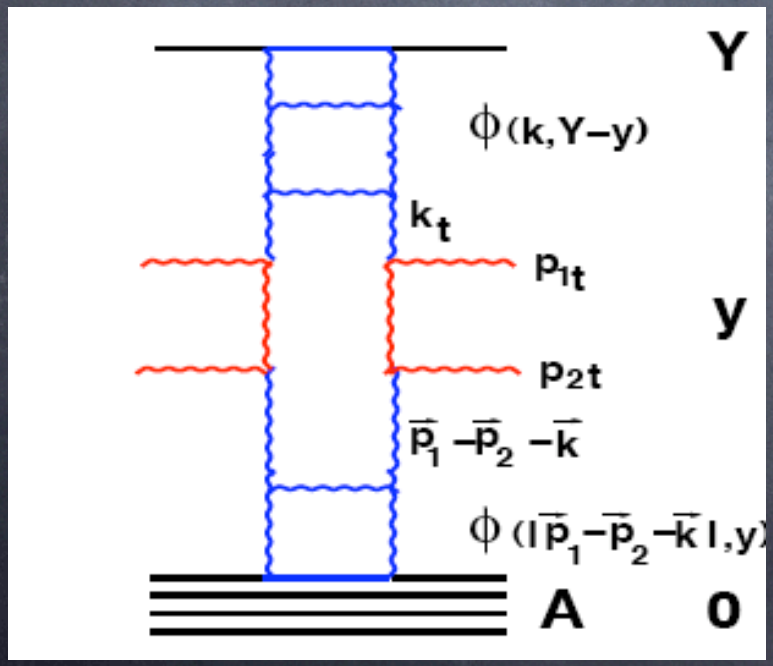


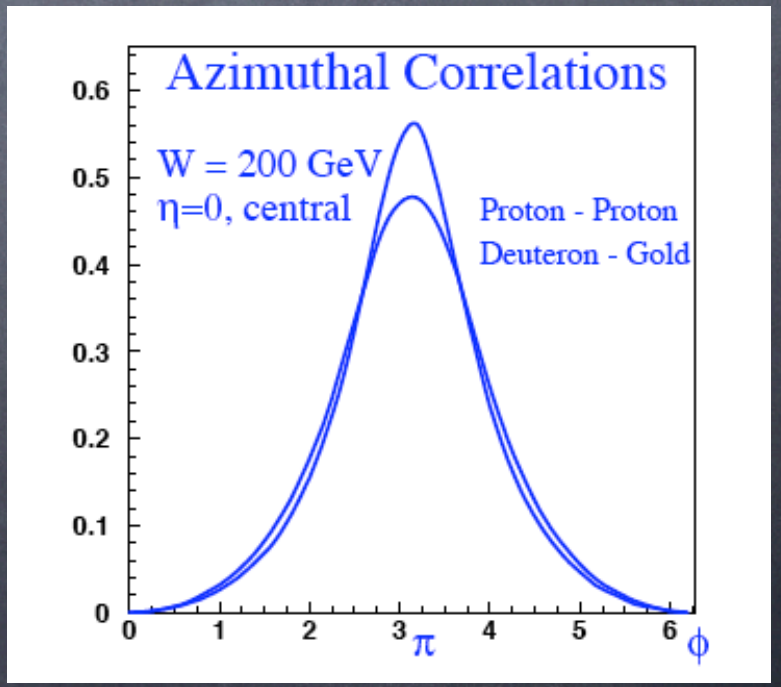


- Transition to completely coherent scattering happens at RHIC!!

Azimuthal correlations

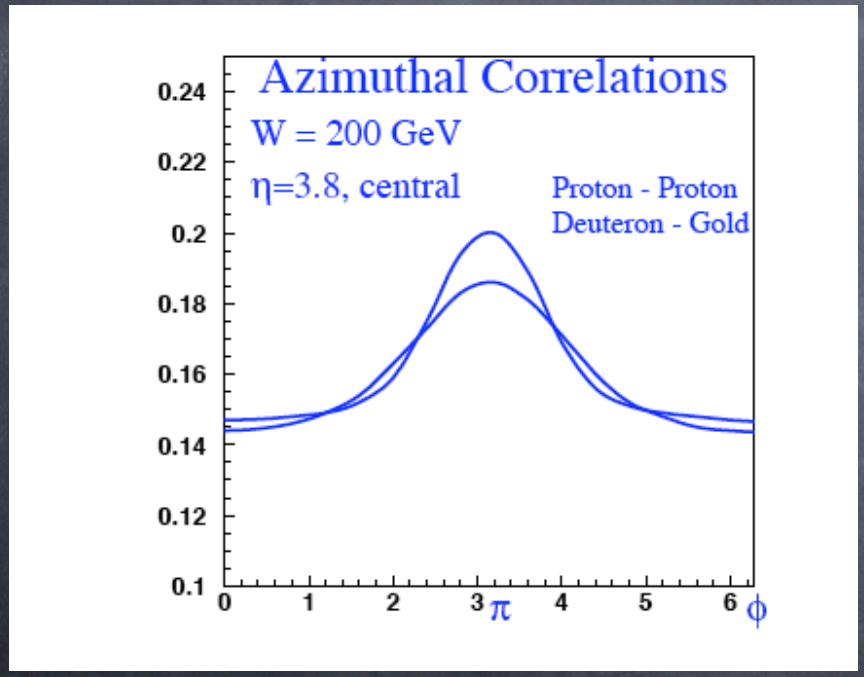
- Azimuthal correlations due to CGC are different from pQCD: they are depleted since the classical fields commute. Prediction: suppression of back-to-back correlation at low x.



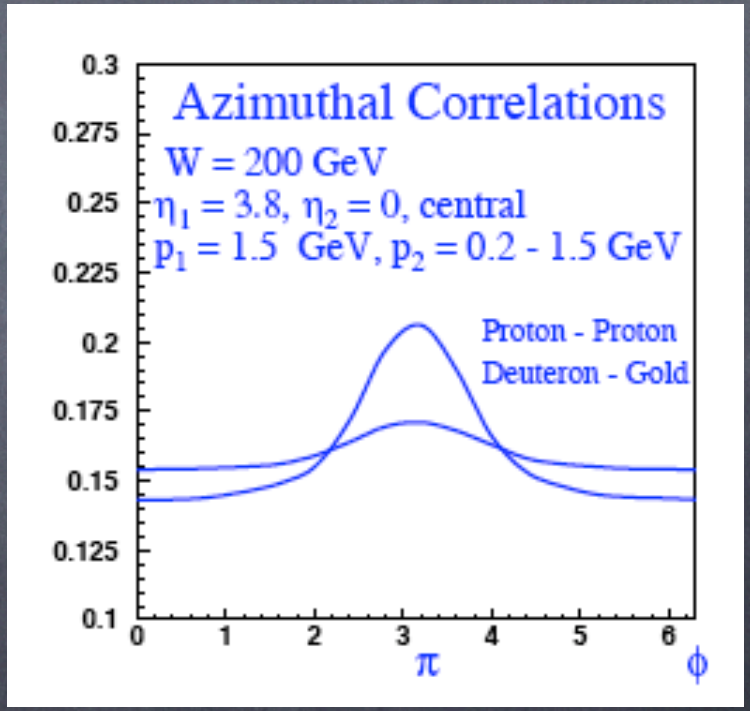


Azimuthal correlations

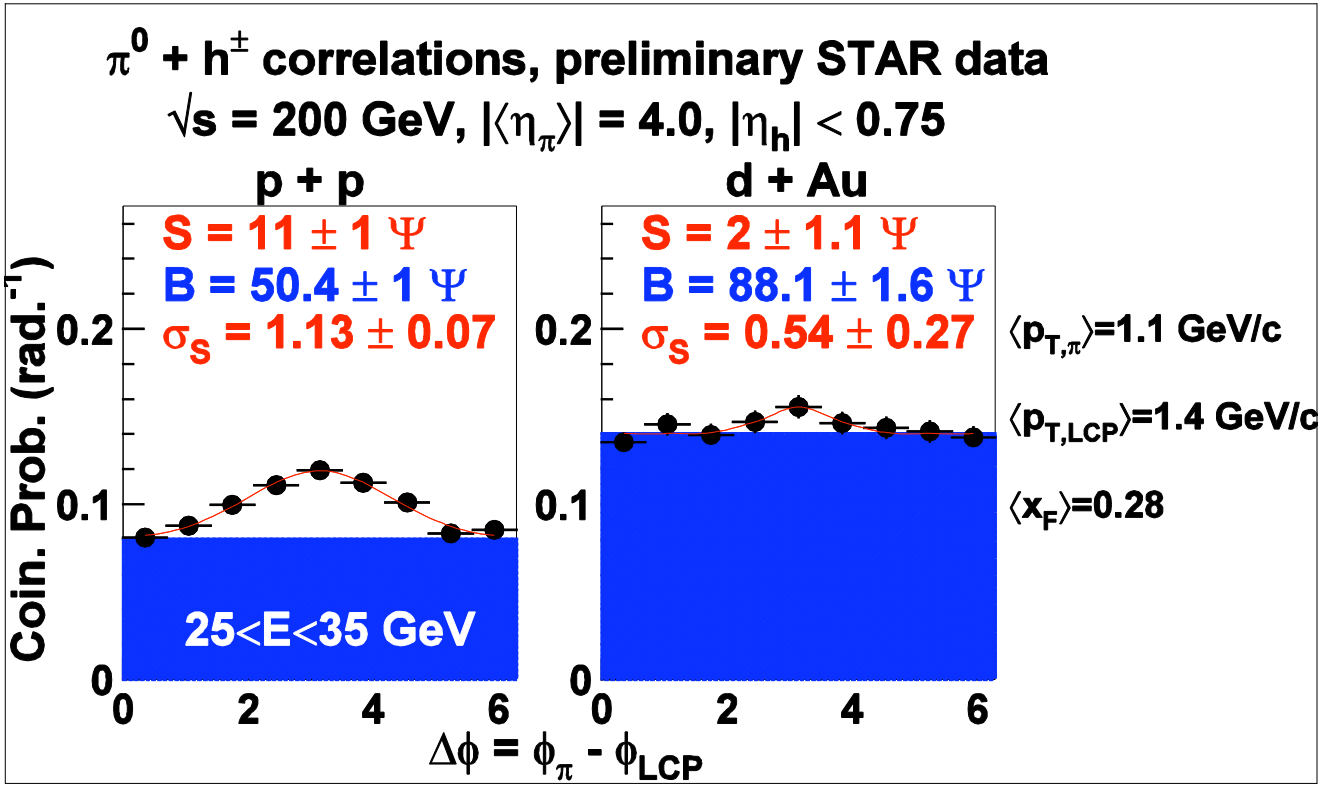
- at forward rapidity:



- backward-forward correlations:

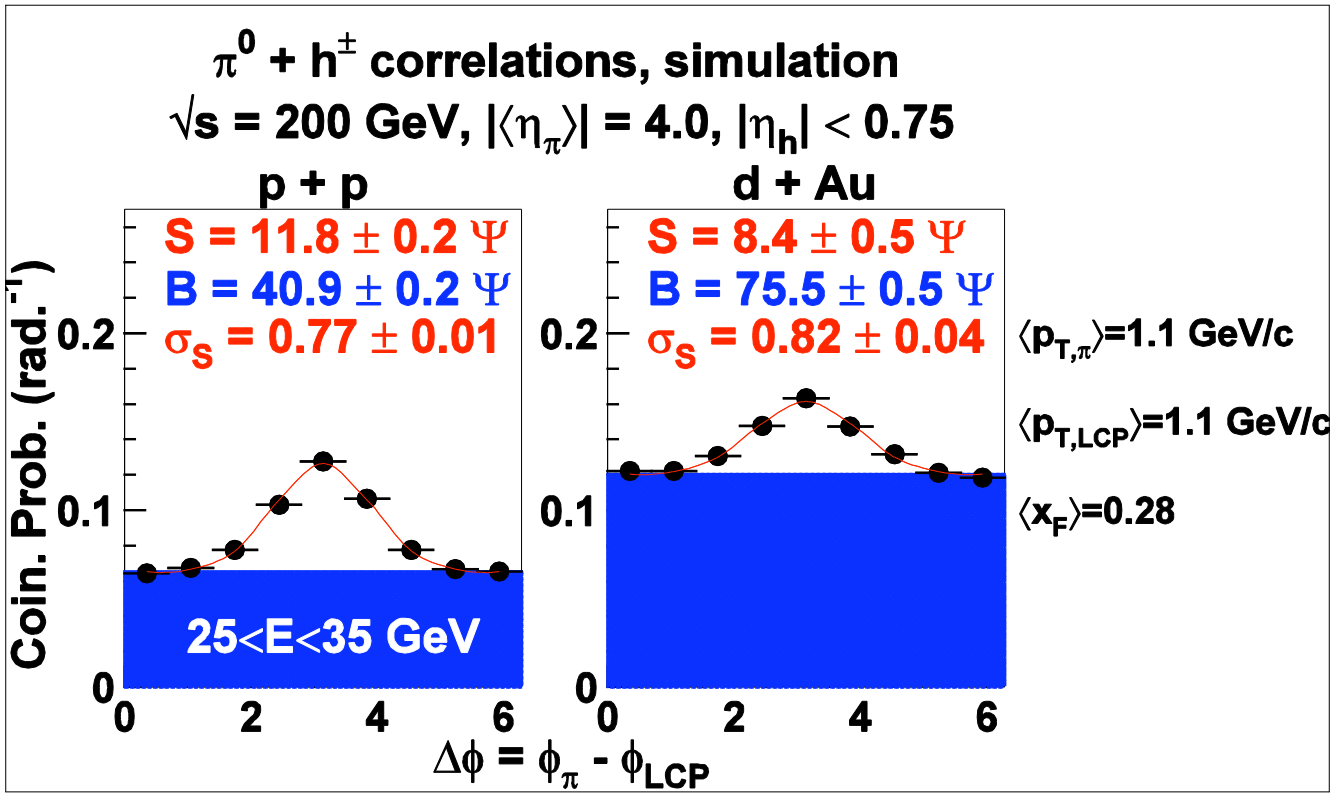


Back-to-back correlations



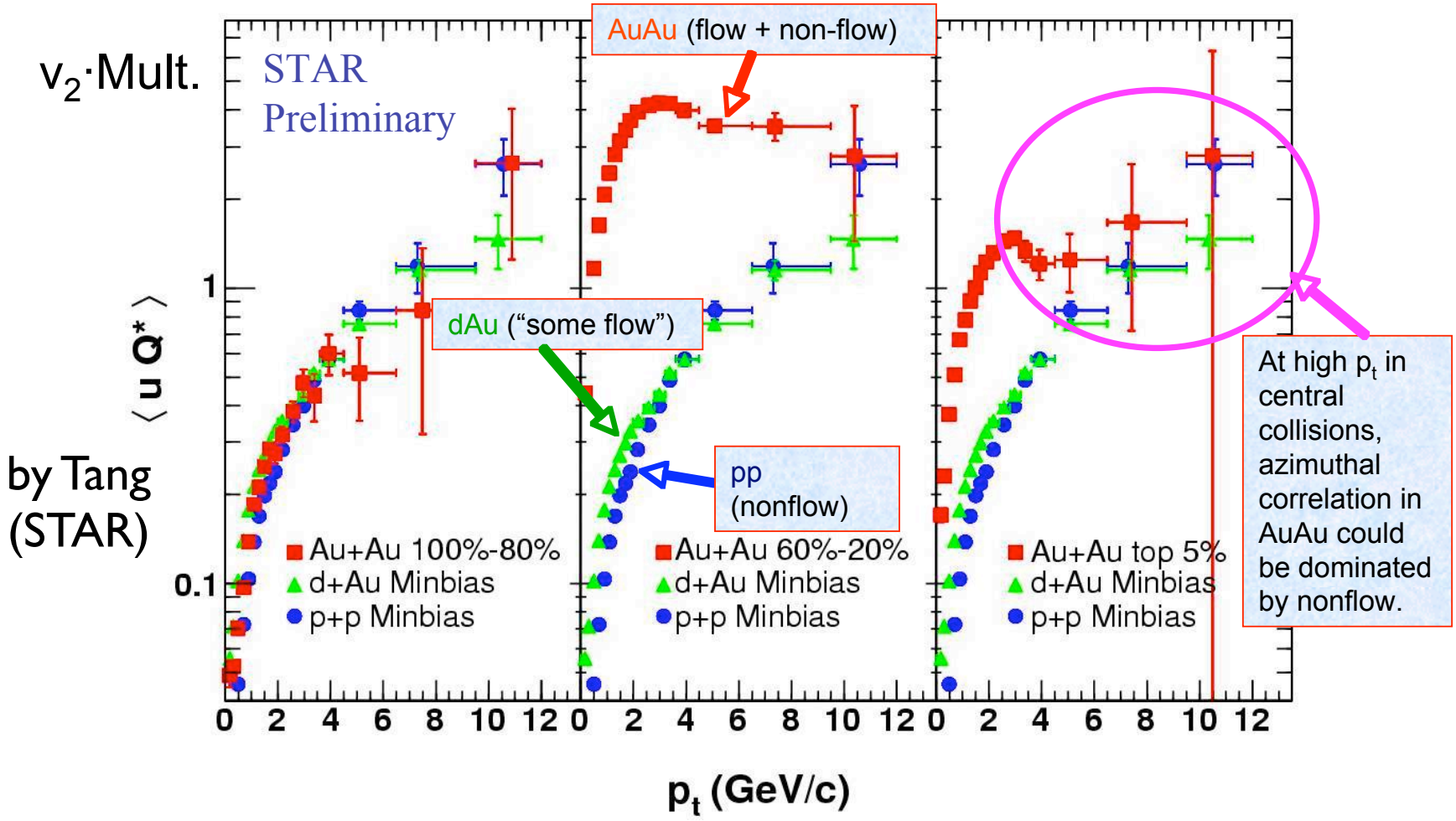
by STAR

Back-to-back correlations



from HIJING

Azimuthal correlations in AuAu, dAu and pp

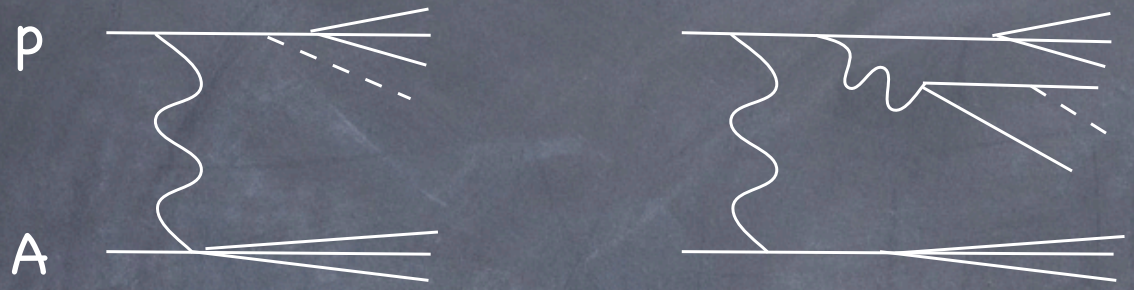


There is a significant "flow" component in dA and pp at large p_T

Azimuthal asymmetry: summary

- It is very interesting and informative, but hard to calculate. It won't be a decisive argument for or against any model/theory.

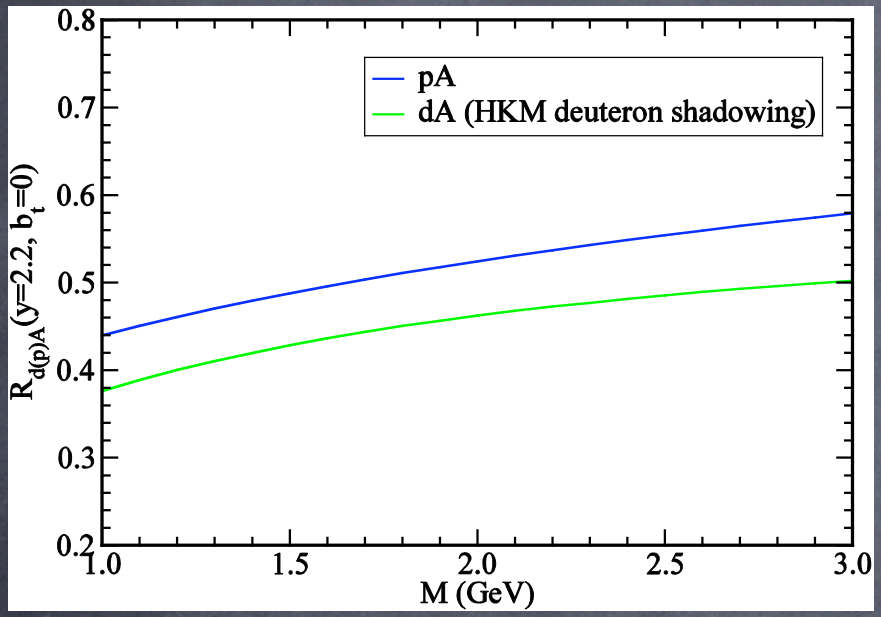
Prompt photons and dileptons



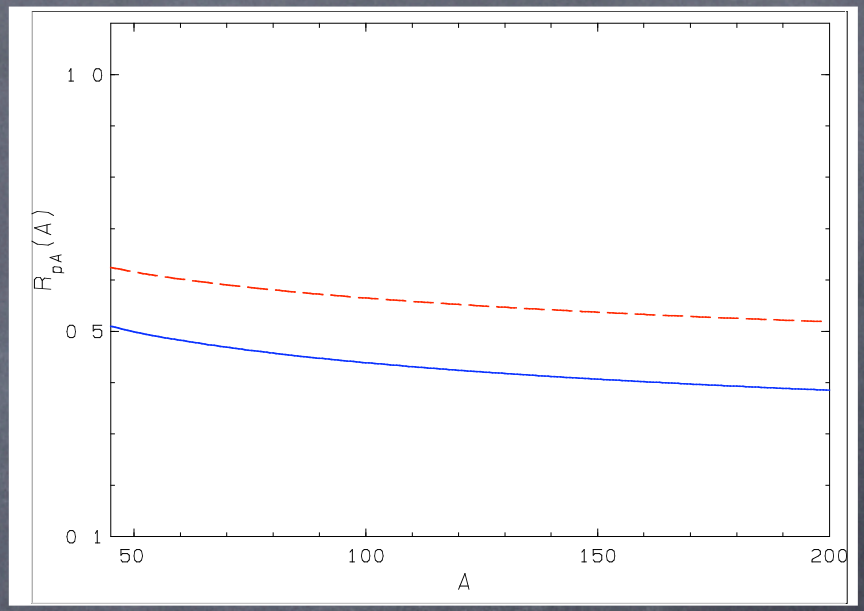
- Advantages of di-leptons:
  - ✓ no need to know the fragmentation functions;
  - ✓ do not strongly interact.

Di-lepton production

Low rates …



R_{dA}(M) integrated over transverse momenta of lepton pair (Jalilian-Marian)



R_{dA}(A) at k_T=5 GeV, M=2 and y=3 (Baier, Mueller, Schiff)

Observables sensitive to power corrections / higher twists

Why higher twists?

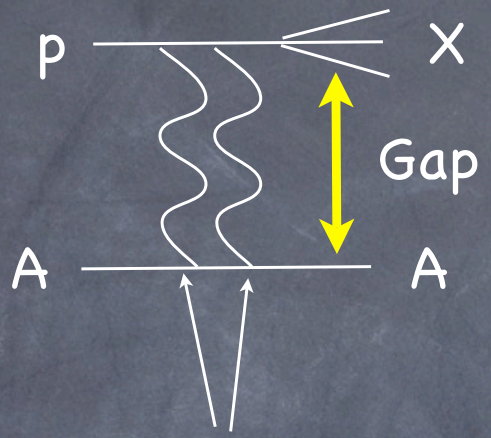
pQCD: $(\Lambda/Q)^{2n}$

CGC: $(Q_s/Q)^{2n}$

Different dependence on A and x!

- Diffractive production: definitely sensitive to higher twists. It is the most important signature of CGC in ep DIS.
- J/ψ and identified hadrons: probably sensitive.

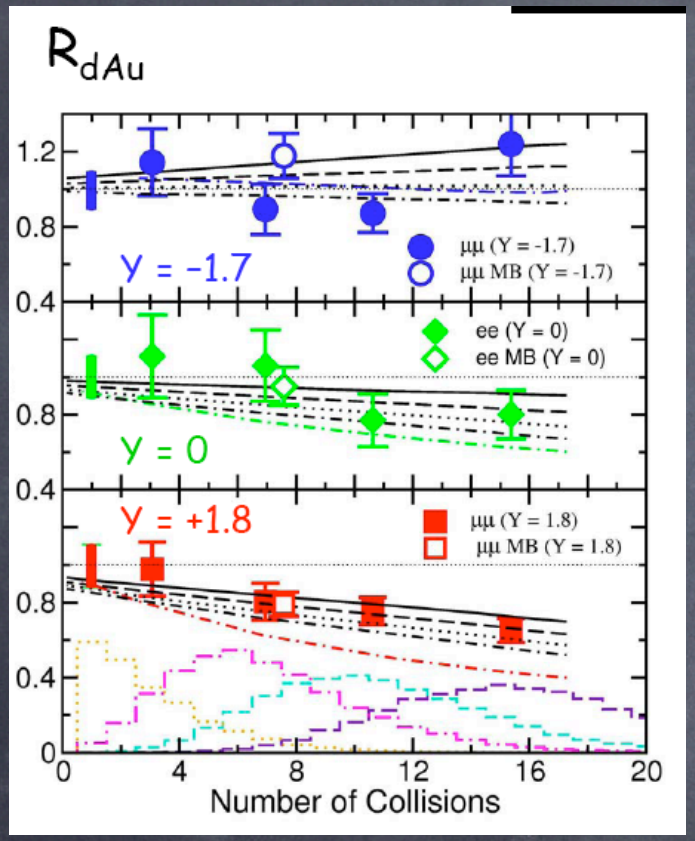
Diffraction

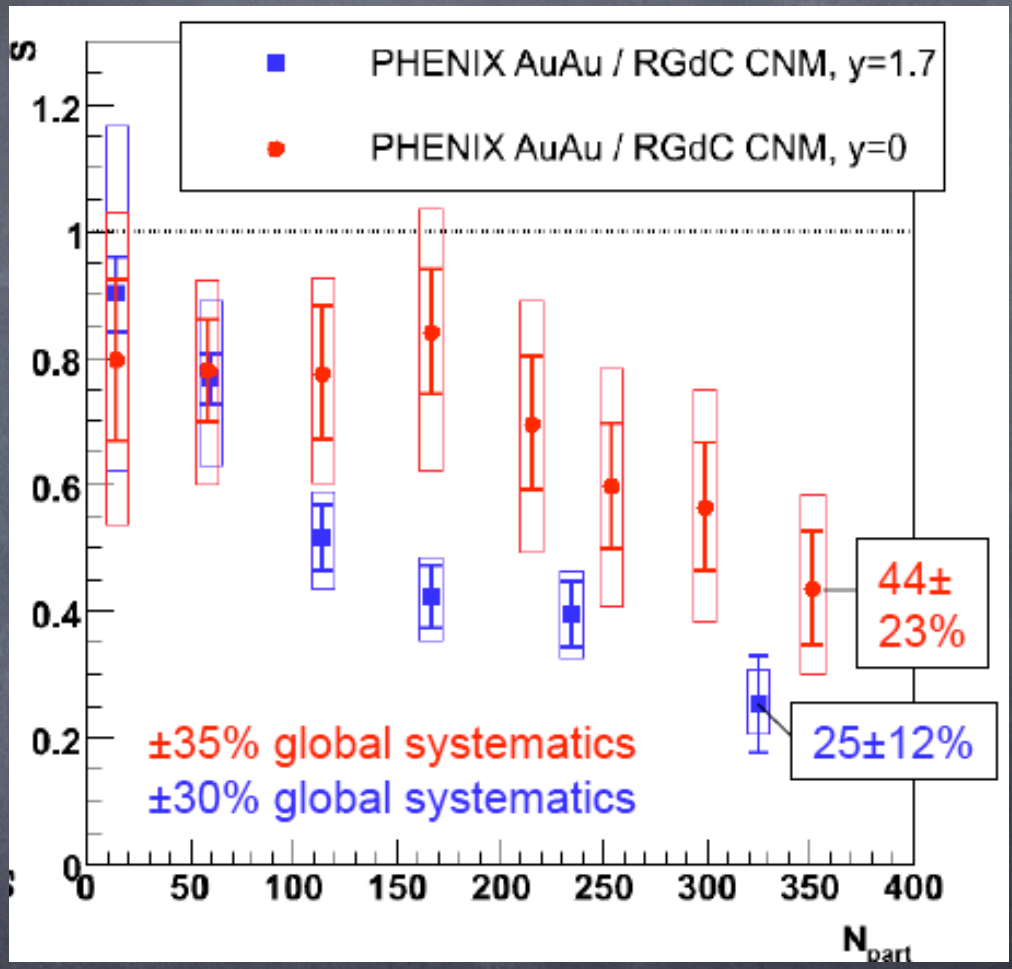


Requires at least two gluon exchange - higher twist

Unitarity: elastic + single diffraction → 50% of all events at very high energies

J/ψ production: experiment (PHENIX)





- Presented by R. Granier de Cassagnac at QM2006

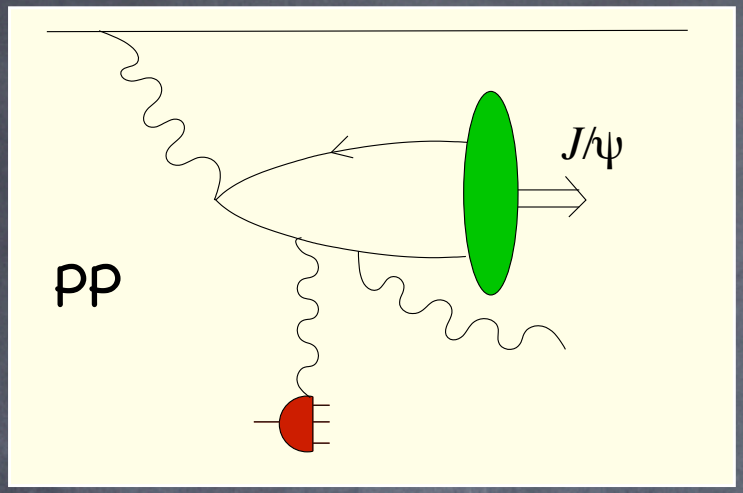
J/ψ production: theory

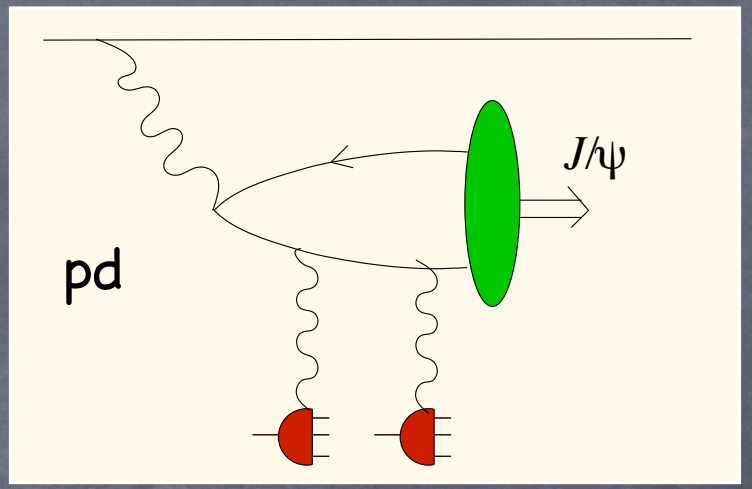
- pQCD calculations by Vogt using shadowing models.
- Nuclear coherence by Kopeliovich et al.
- CGC

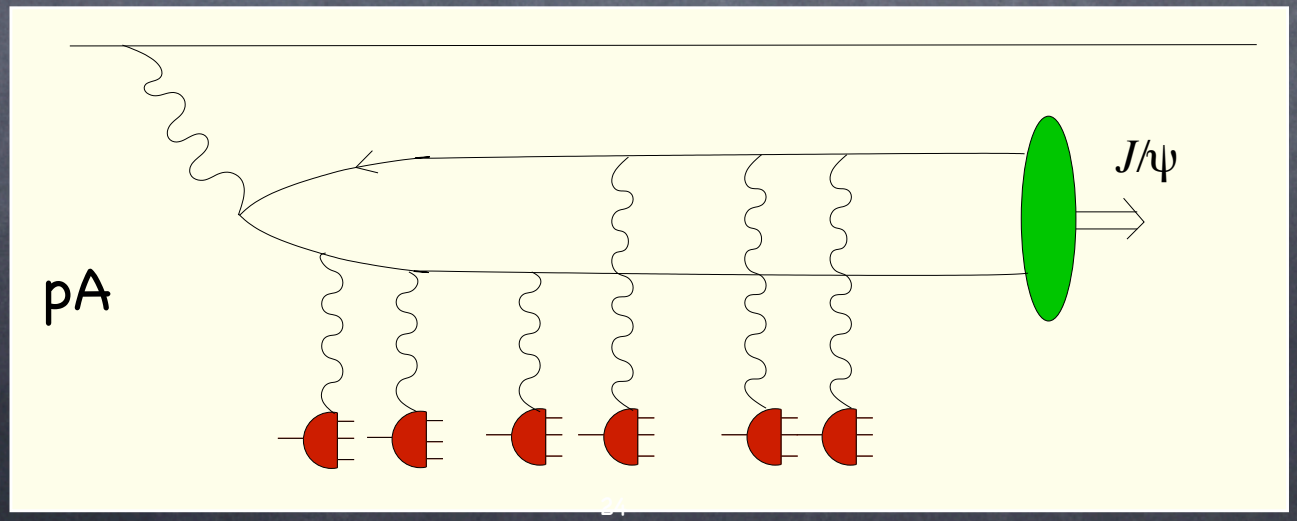
d/p A has a tremendous potential to shed light on J/ψ production!

J/ψ production mechanism is essentially different from the open charm!

J/ψ production







Baryon/Meson ratio

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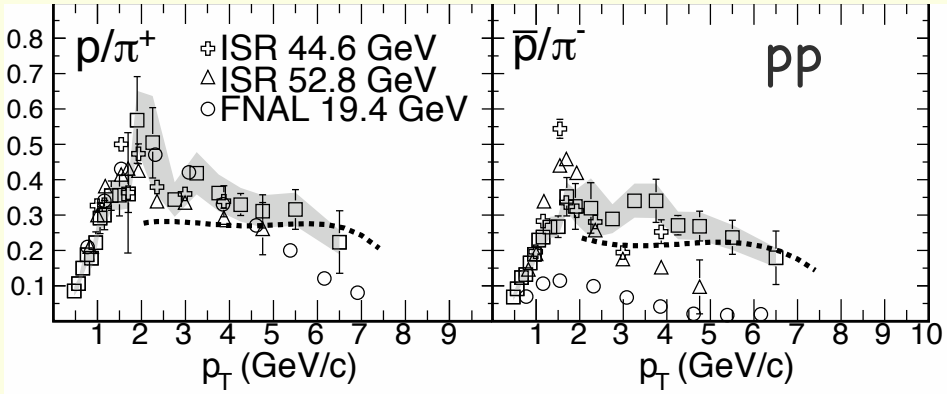
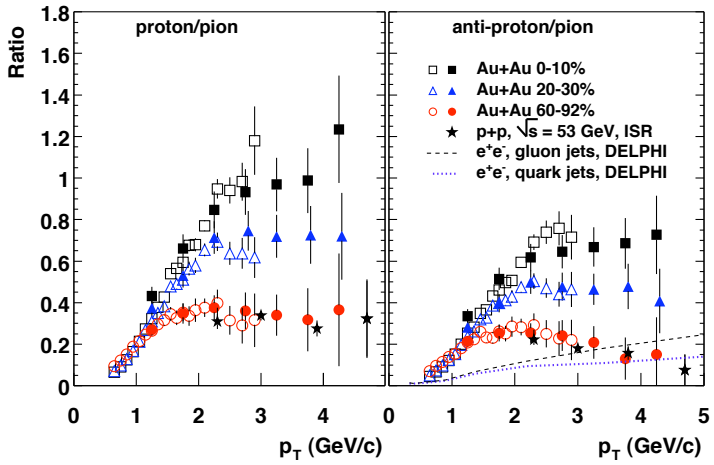


PHENIX



- In pQCD B/M ratio is energy and A-independent.
- Data: B/M is not constant: a possible signature of higher twists.

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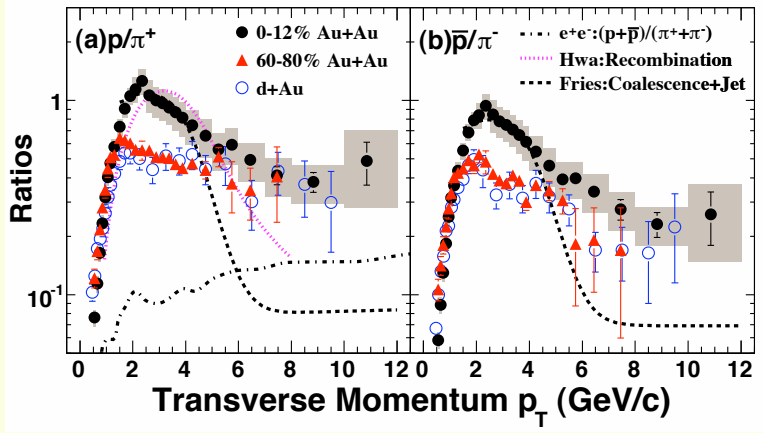

Summary

- Hadron spectra: need as high p_T as possible, forward η.
- J/ψ: p(d)A has a potential to shed light on its mysterious production mechanism.
- Correlations: at high p_T will be more conclusive.
- Prompt photons and di-leptons: the cleanest probe of the initial state.
- Identified hadrons: fragmentation bears signatures of power corrections.
- Diffraction: a strong model killer.